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***Y02E 10/50*** (2013.01)

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USPC ..... 438/72, 57, 69  
See application file for complete search history.

- (56)
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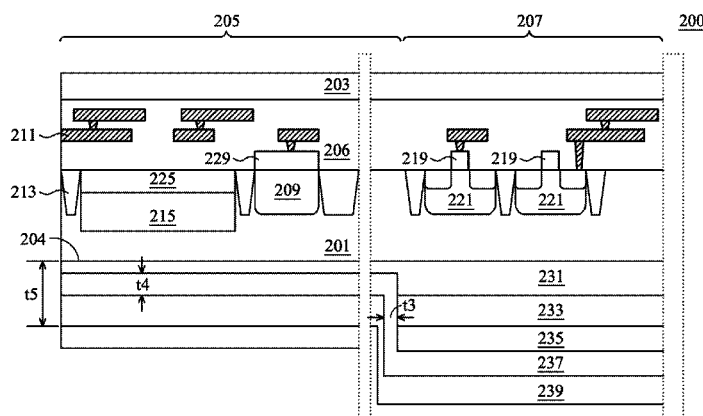
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(57) **ABSTRACT**

- BSI image sensors and methods. In an embodiment, a substrate is provided having a sensor array and a periphery region and having a front side and a back side surface; a bottom anti-reflective coating (BARC) is formed over the back side to a first thickness, over the sensor array region and the periphery region; forming a first dielectric layer over the BARC; a metal shield is formed; selectively removing the metal shield from over the sensor array region; selectively removing the first dielectric layer from over the sensor array region, wherein a portion of the first thickness of the BARC is also removed and a remainder of the first thickness of the BARC remains during the process of selectively removing the first dielectric layer; forming a second dielectric layer over the remainder of the BARC and over the metal shield; and forming a passivation layer over the second dielectric layer.

- 20 Claims, 7 Drawing Sheets**

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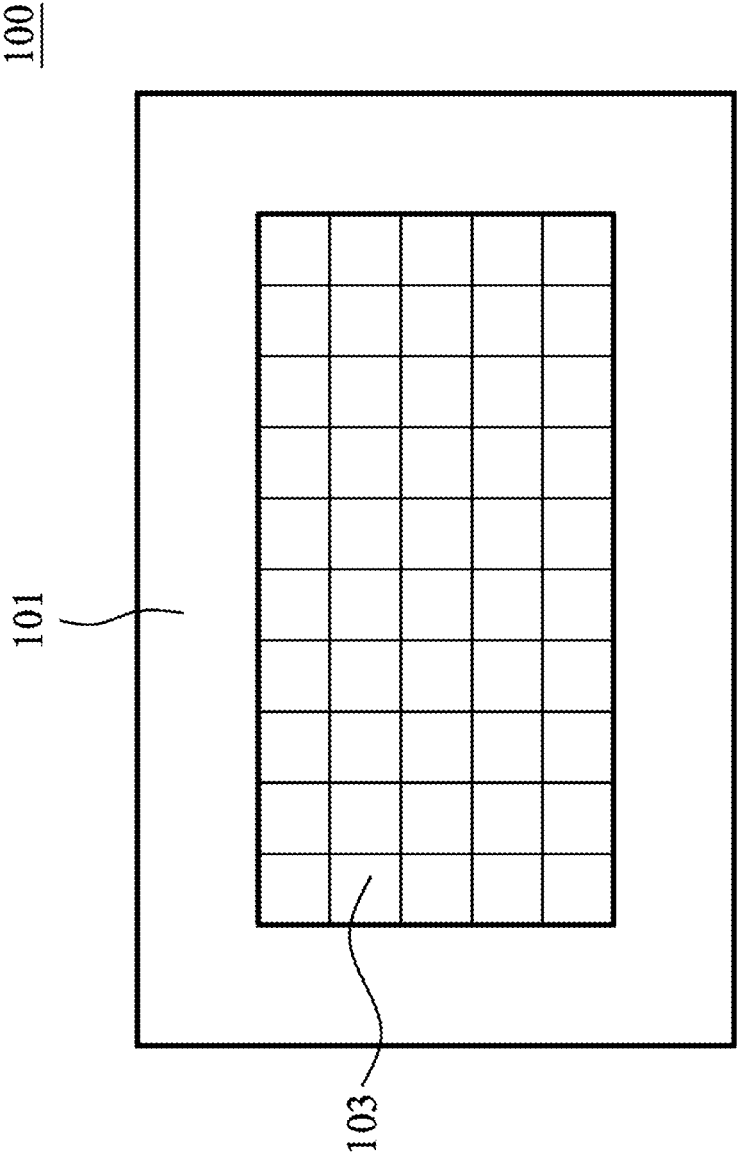


Figure 1

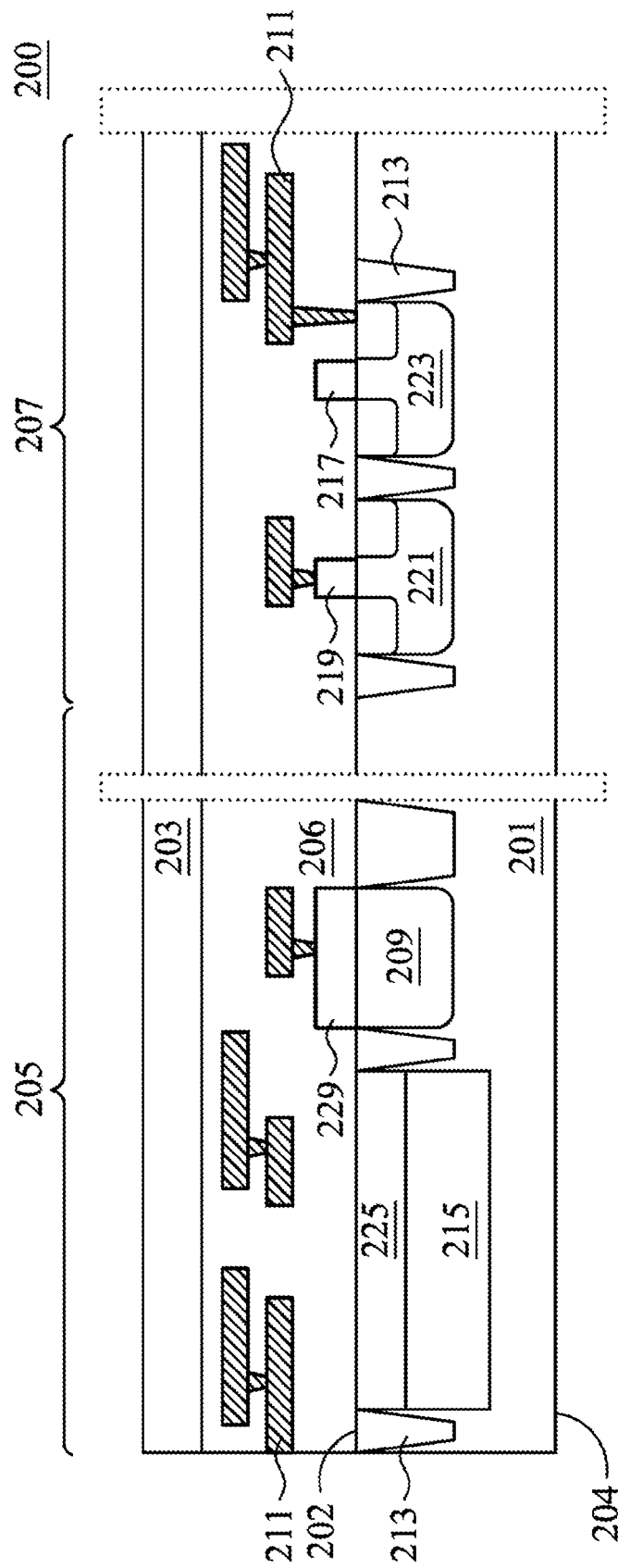


Figure 2

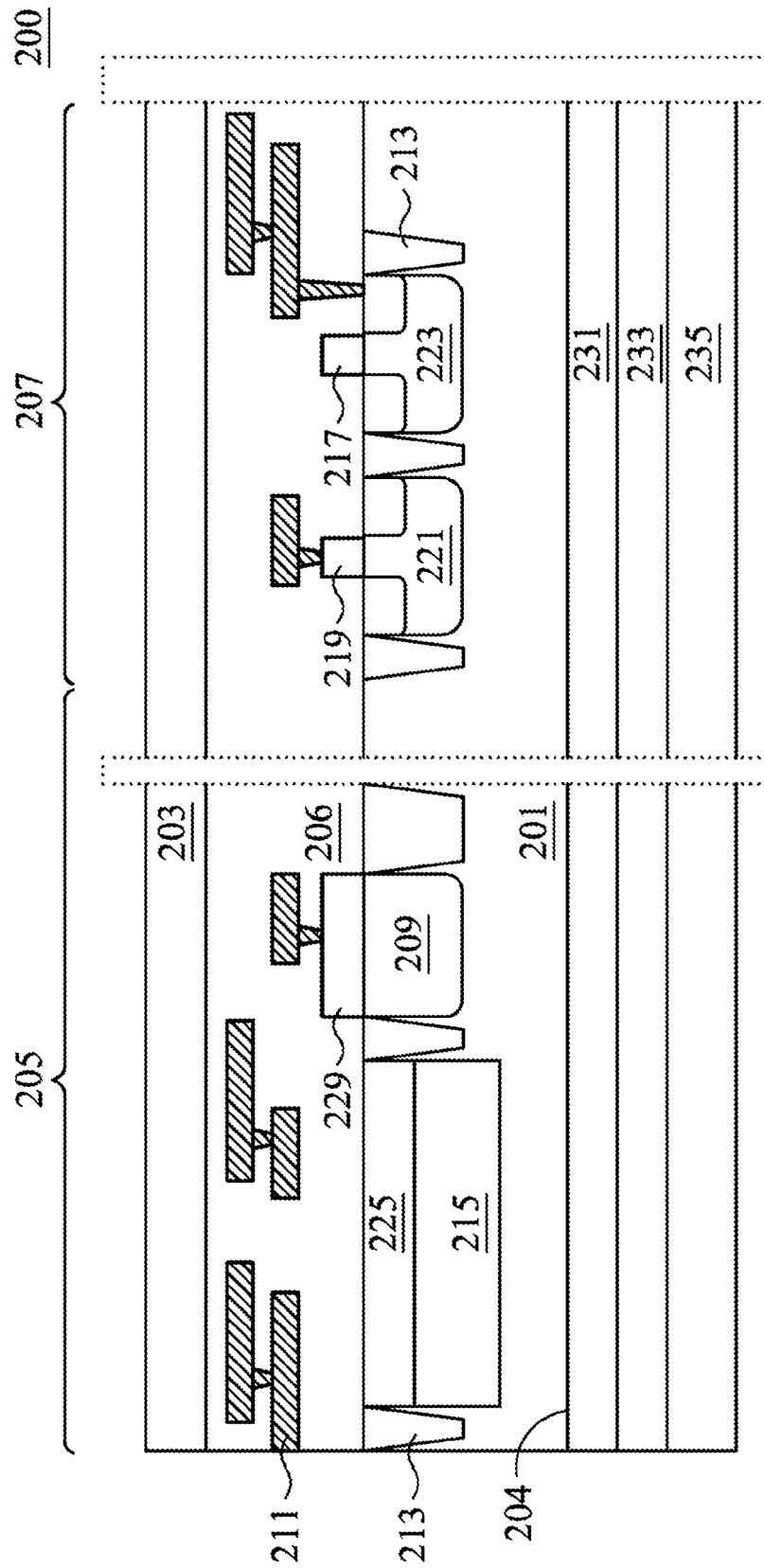


Figure 3

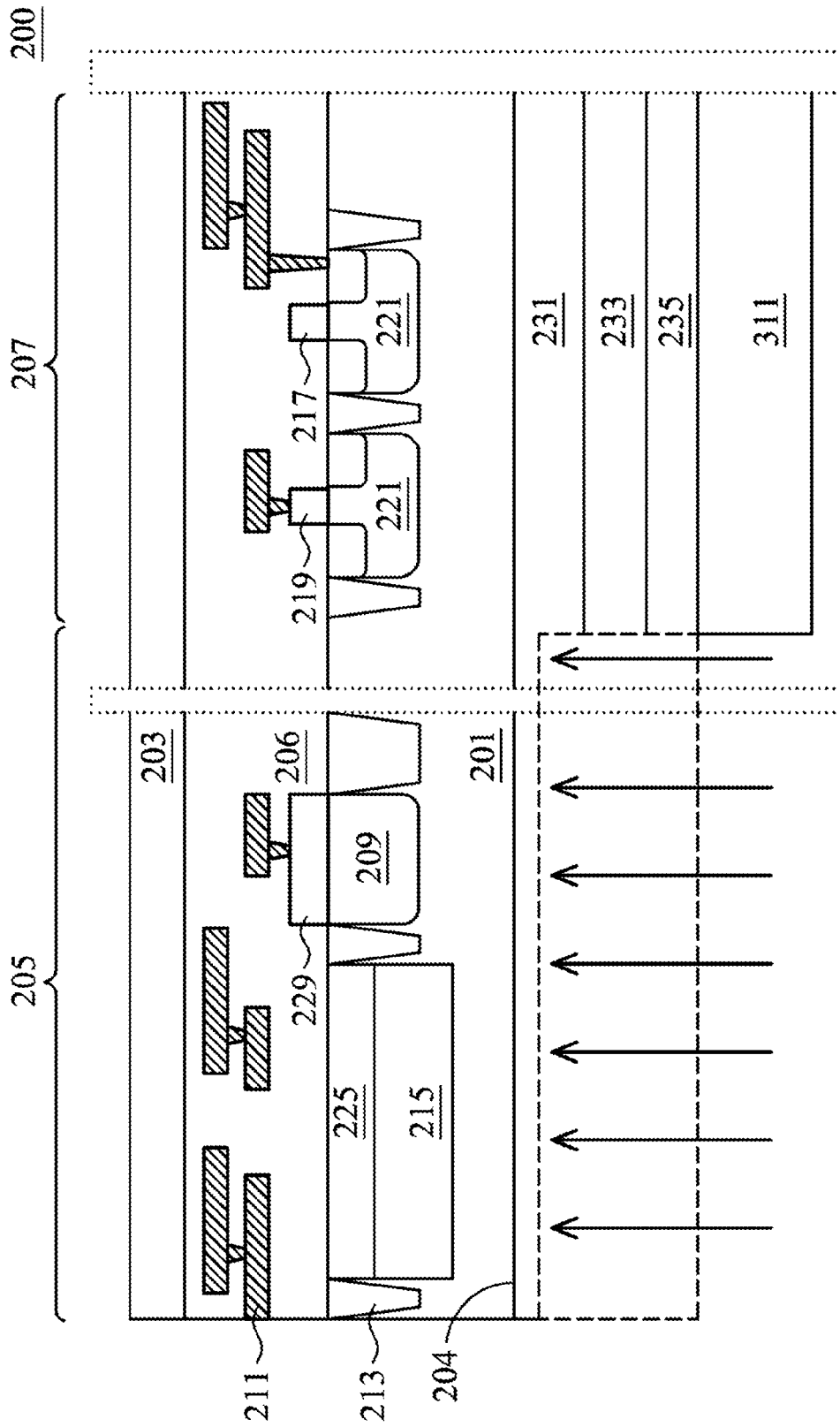


Figure 4

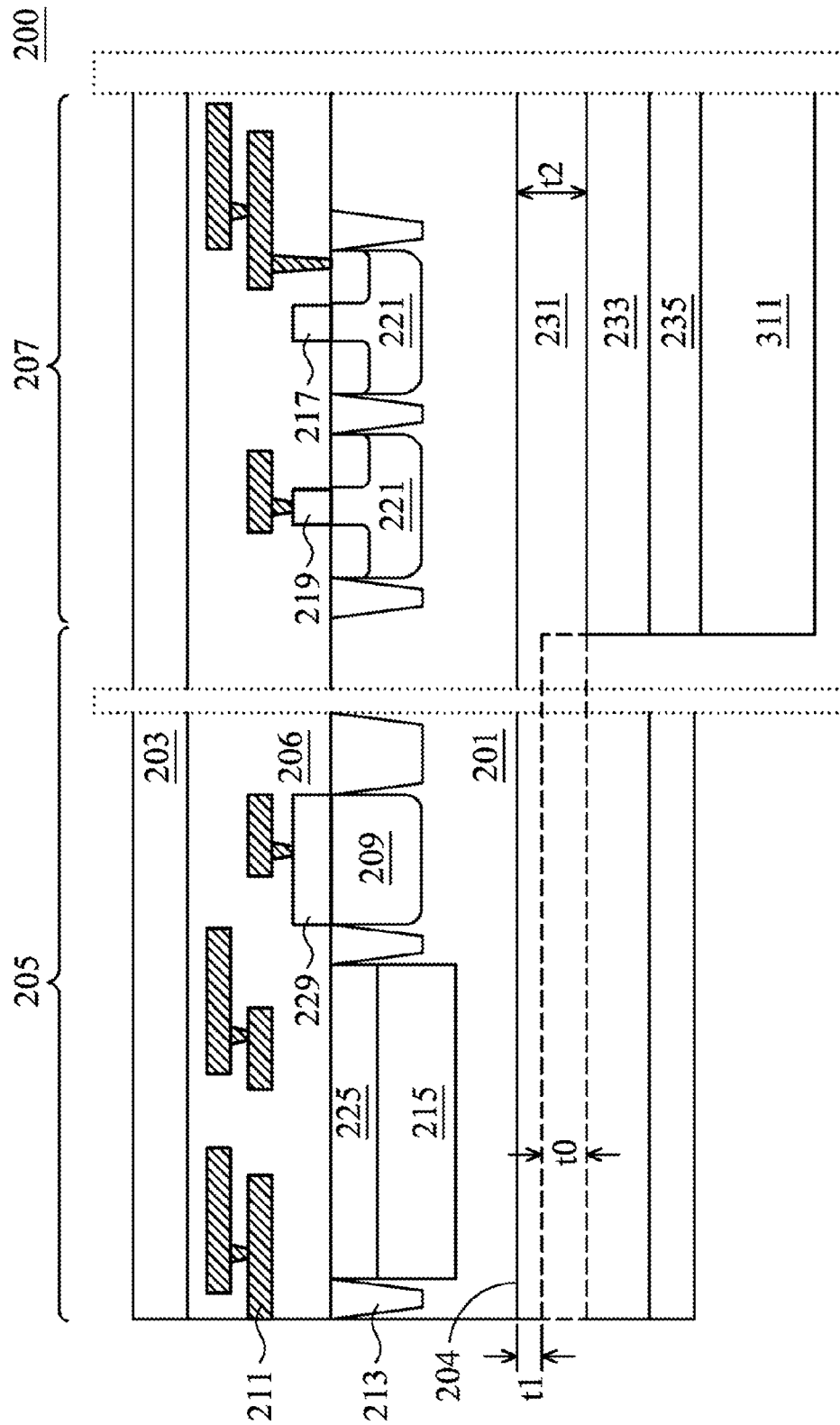


Figure 5

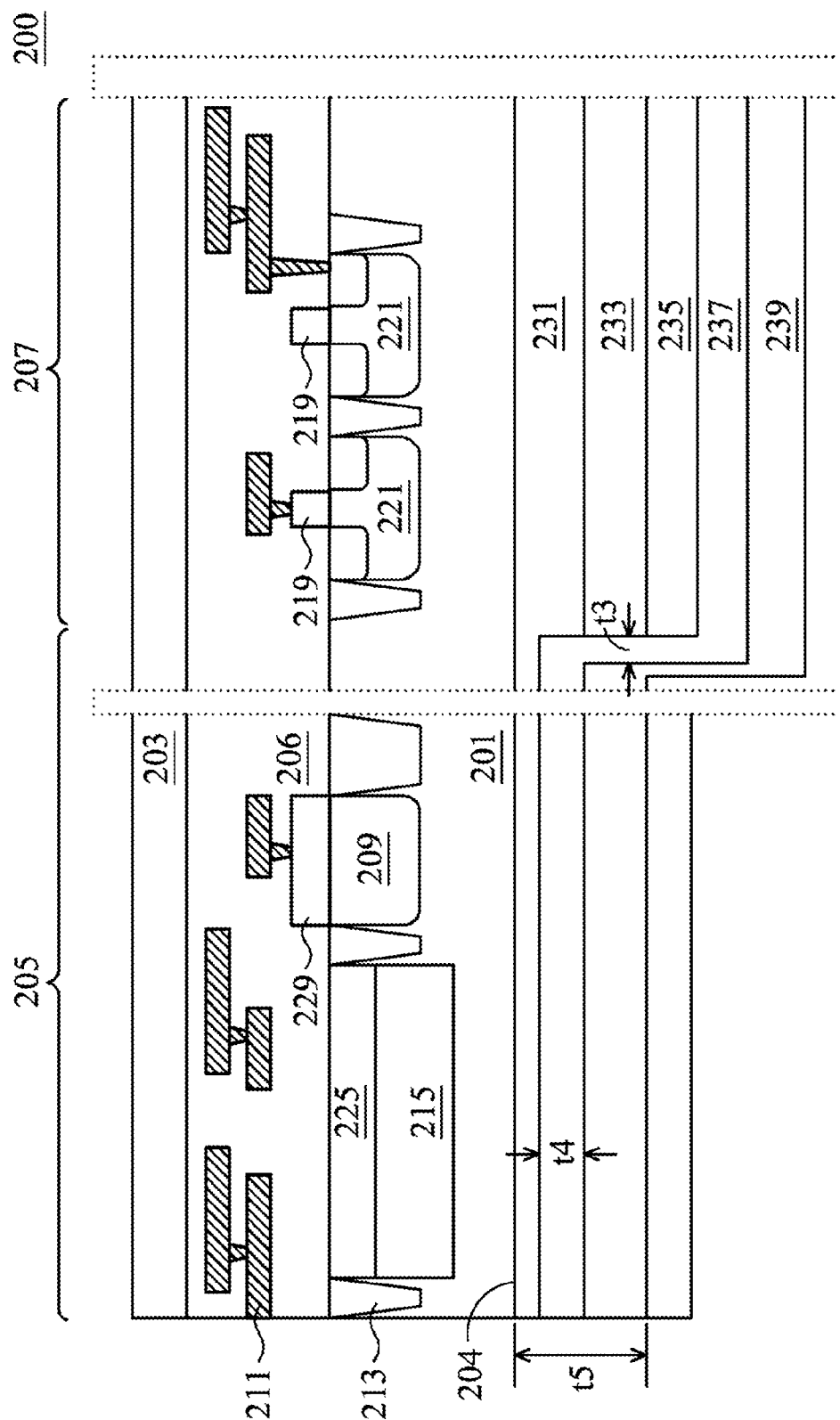


Figure 6



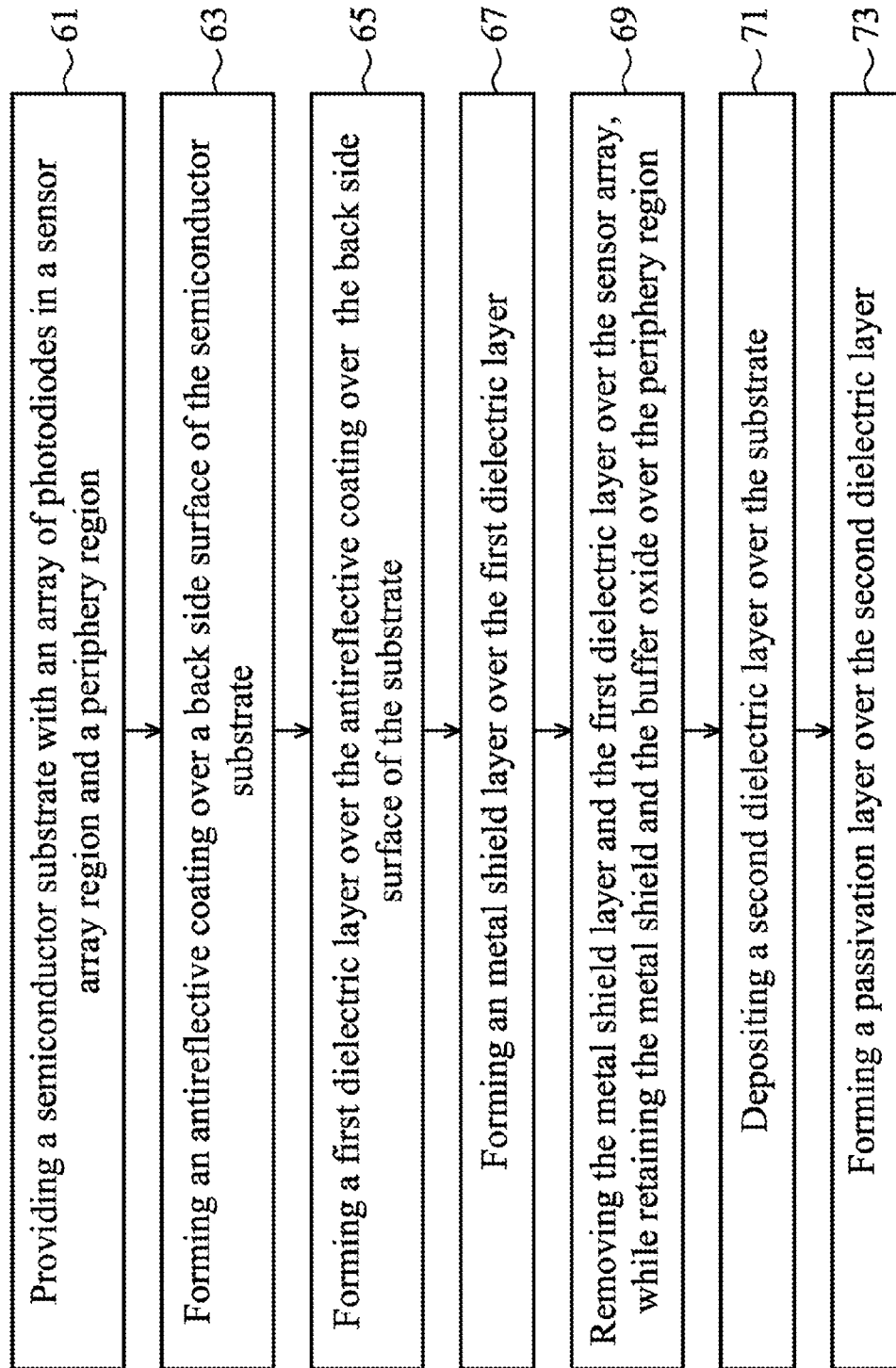


Figure 7

## BACKSIDE STRUCTURE AND METHOD FOR BSI IMAGE SENSORS

This application is a continuation application of and claims the benefit of U.S. patent application Ser. No. 14/178,084, filed Feb. 11, 2014 and entitled "Backside Structure and Methods for BSI Image Sensors," which is a divisional application of U.S. patent application Ser. No. 13/620,016, now U.S. Pat. No. 8,709,854, filed Sep. 14, 2012 and entitled "Backside Structure and Methods for BSI Image Sensors," which claims the benefit of provisionally filed U.S. Patent Application Ser. No. 61/645,376, filed May 10, 2012 and entitled "Backside Structure for BSI Image Sensor," which applications are hereby incorporated herein by reference.

### BACKGROUND

Back Side Illumination (BSI) images sensors such as BSI CMOS image sensors are becoming increasingly popular because of their compatibility with conventional CMOS manufacturing processes, low cost, small size, and high performance. CMOS image sensors are replacing more traditional charge coupled device (CCD) sensors due to certain advantages, including that CMOS image sensors consume less power, are compatible with CMOS semiconductor processes, and the sensors may be integrated with additional CMOS logic devices on a single integrated circuit device. Conventional CMOS manufacturing processes, however, are not necessarily tuned for BSI image sensors and current manufacturing processes may cause less than desirable device performance, particularly on the performance criteria of quantum efficiency (QE), signal to noise ratio (SNR), and light mean value uniformity.

In forming a BSI image sensor, semiconductor processing is used to form an array of photodiodes (PDs) and the associated MOS transfer transistors in a sensor array for integrated circuit dies on a semiconductor wafer, and to form periphery circuit MOS devices such as input-output buffers in the integrated circuit dies on the semiconductor wafer. As the photodiodes are exposed to light, an electrical charge is induced in the photodiodes corresponding to the light intensity. The MOS transfer transistor may sample the charge and transfer charge to a storage node for further processing. Color pixels may be formed by placing color filters over the light sensitive CMOS circuitry.

To form the BSI image sensor, after the CMOS photodiodes and MOS transistors are formed, additional semiconductor processing is performed on the back side (the side free from metallization layers and interlayer dielectrics) of the semiconductor wafer. In conventional BSI processing, the processing includes forming a buffer oxide and a metal shield over the wafer. The buffer oxide and metal shield are then selectively removed from the sensor array area of the integrated circuit dies, while the metal shield is retained over the periphery area.

However, in the conventional semiconductor processing, an etch to remove the metal shield from the sensor array areas also removes either a portion of, or all of the buffer oxide layer. The conventional etch process results in either a non-uniform buffer oxide thickness or no oxide thickness over the sensor array areas, which negatively impacts the performance of the BSI image sensor.

### BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the present invention, and the advantages thereof, reference is now made to the following descriptions taken in conjunction with the accompanying drawing, in which:

FIG. 1 depicts in a plan view a BSI image sensor device;

FIG. 2 illustrates in a cross sectional view an intermediate stage in the manufacture of an illustrative embodiment BSI image sensor device;

FIG. 3 illustrate in a cross sectional view the BSI image sensor device of FIG. 2 following additional processing steps;

FIG. 4 illustrates in a cross sectional view the BSI image sensor device of FIG. 3 following additional processing steps;

FIG. 5 illustrates in a cross sectional view the BSI image sensor device of FIG. 4 following additional processing steps;

FIG. 6 illustrates in a cross sectional view the BSI image sensor device of FIG. 5 following additional processing steps; and

FIG. 7 illustrates method embodiment in a flow diagram.

Corresponding numerals and symbols in the different figures generally refer to corresponding parts unless otherwise indicated. The figures are drawn to clearly illustrate the relevant aspects of the preferred embodiments and are not necessarily drawn to scale.

### DETAILED DESCRIPTION

The making and using of illustrative example embodiments are discussed in detail below. It should be appreciated, however, that this application provides many applicable inventive concepts that can be embodied in a wide variety of specific contexts. The specific embodiments discussed herein are merely illustrative of specific ways to make and use embodiments, and do not limit either the scope of this application or of the appended claims.

Before discussing the illustrated embodiments specifically, various embodiments and advantageous features thereof will be discussed generally. For instance, advantageous features of some embodiments may include improved QE, SNR, and light mean uniformity and light value performance. Some embodiments allow fine tuning of the thicknesses of layers in the light path of the image sensor to tune the color light mean value and color ratio of the device. As illustrated below, embodiments disclosed herein provide for a relatively simple structure and low cost semiconductor processes that nonetheless provide for improved performance as discussed herein. One skilled in the art will recognize that the teachings provided herein can be readily applied to present and future generation processes for manufacturing image sensors.

Both front side illumination (FSI) and BSI image sensors are known. However, when using a FSI image sensor, the light impinging on a photodiode in the sensor must first pass through the metallization layers and the interlayer dielectric material overlying the front side of the substrate, which reduces the light level impinging on the photodiode, lowers the QE, increases the noise (lowers SNR), and generally reduces performance of the sensor device. BSI image sensors are therefore increasingly used. In a BSI image sensor such as those described in the embodiments, the light enters the semiconductor substrate from the back side, and the light impinging on the photodiodes traverses a relatively thin semiconductor layer and without having to traverse any overlying metallization layers and interdielectric layers, in sharp contrast to the FSI image sensors. Use of BSI image sensors may therefore increase image sensor performance.

With reference now to the illustrative embodiments, FIG. 1 depicts in a top view a BSI image sensor 100. The image sensor 100 may be an integrated circuit including an array region of photodiodes 103 and a periphery region 101. Each photodiode 103 may include a photosensitive diode (p-n junction) and associated transistors for receiving signals proportional to the intensity or light received by the photosensitive

diodes during a light sampling interval. Circuitry for providing functions other than photodiodes, such as input output buffers and logic circuitry, may be formed in the periphery region **101**. This additional circuitry may include logic circuitry for operating the sensor array and circuitry for communicating the data corresponding to the sensed light to external devices. The periphery region **101** is positioned adjacent to the sensor array region **103**. The integrated circuit device **100** may be formed on a semiconductor substrate such as silicon, germanium arsenide, or other semiconductor material. In an example embodiment, the integrated circuit **100** may be formed on a silicon wafer. A silicon wafer may have hundreds or thousands of image sensor integrated circuits such as **100** formed on it, using conventional semiconductor processes.

FIG. 2 shows in a cross sectional view an illustrative embodiment device **200**, a BSI image sensor, at an intermediate stage of manufacture. FIG. 2 illustrates only a portion of the device **200**. In a practical example, an image sensor device will include many hundreds or thousands of photodiodes in a sensor array area **205**. Further, typically the device **200** is formed on a semiconductor wafer that may include many hundreds or thousands of BSI integrated circuit devices arranged as individual dies on each semiconductor wafer. Processing steps and details not necessary to understanding the embodiments are omitted herein for clarity.

In the intermediate processing stage, shown in the cross section of FIG. 2, a semiconductor substrate **201** has been processed to include the sensor array region **205** and a periphery region **207**, the manufacture and function of which will be clear to those skilled in the art.

In FIG. 2, semiconductor substrate **201** has a front side **202** and a back side **204**. The semiconductor substrate **201** may be of a semiconductor material such as silicon, germanium, and diamond or like materials. Compound materials used for semiconductor substrates such as silicon germanium, silicon carbide, gallium arsenide, indium arsenide or indium phosphide, and combinations of these, may be used. In alternative embodiments, the substrate **201** may comprise a silicon on insulator (SOI) substrate.

As shown in FIG. 2, semiconductor substrate **201** has been processed using front end of the line (FEOL) processes to form a photodiode in a diffusion region **215** including a second diffused region **225** in the sensor array region **205**. Diffused regions **221** and **223** in the periphery region **207** form doped wells that may be used, for example, to form CMOS logic transistors in the periphery region **207**. Isolation structures **213** are shown between the diffused regions; these may be shallow trench isolation (STI) or LOCOS isolation. Gate structures **217**, **219**, and **229** may be formed as patterned gate conductors overlying the diffused regions including a gate dielectric and a conductor, and may be formed of a doped polysilicon material for example, or by using metal gate processes. The gate dielectric material (not visible) may be silicon dioxide, or high or low-k gate dielectric material. Diffused region **209** and gate **229** may form a photodiode transfer transistor. The transfer transistor may be used for transferring charge corresponding to the light sensed by the photodiode in diffusion **215** during a sampling interval into a storage node (not shown), for example. The photodiode may be formed as a diffusion region **215** of one doping type, such as an n type, and a second diffusion region of an opposing doping type **225**, such as a p type, to form a p-n junction for a photodiode. Pinned photodiodes may be used. The sensor array region **205** may also include pixel circuitry such as transfer gate **229**, and in addition reset transistors, source follower transistors, and read select transistors for each photo detector may be formed

in the sensor array region **205**. Three transistor (3T) and four transistor (4T) pixel circuits, for example, may be formed with the photodiodes in the sensor array region **205**.

After manufacturing the BSI array as further described below, color filters (not shown) that selectively pass light of certain frequencies which may include red, green and blue colors (R/G/B) are formed over the back side **204** of semiconductor substrate **201** over the sensor array region **205** to create color pixels. Microlens material (not shown) may be formed over the color filters to further improve the light reception. As semiconductor process technologies advance, device sizes continue to shrink, including the size of the photodiodes and thus the light sensitivity of the image sensors produced is reduced. This makes the quantum efficiency (QE) and signal to noise ratio (SNR) characteristics ever more critical. Cross-talk effects can also increase especially for longer wavelength light, such as red light. The ability to tune the light path to the photodiode enables accomplishing higher performance image sensors for various applications. Embodiments presented herein enable tuning of the layers the light path.

In FIG. 2, metallization layers **211** are shown overlying the semiconductor substrate **201** on the front side surface **202** and the metallization layers **211** are formed within a dielectric layer **206**. A front side passivation layer **203** overlies the front side **202** of the substrate **201**. (Note that while the front side **202** of the semiconductor substrate **201** is depicted facing upwards in the figures, the position of the substrate and the overlying layers is arbitrary in the figures, and rotating the device **200** does not change the functions and relative positions of the elements shown. As depicted in the figures, the back side **204** of the semiconductor substrate is shown oriented facing downwards; however, this does not change which portion is the back side of the device **200**, even when the orientation is different.)

FIG. 3 depicts the illustrative embodiment device **200** from FIG. 2 following additional processing steps. In FIG. 3, a bottom antireflective coating (BARC) layer **231** is shown formed over the back side **204** of the semiconductor substrate **201**. (Note that the terms "on," "over," "above" and "like" are relative terms, regardless of whether the layers are being added to the nominal "top" of the device or to the nominal "bottom" of the device as illustrated in the figures). The BARC layer **231** may be, for example, a silicon nitride, silicon oxynitride or carbon containing layer such as silicon carbide and may be formed by CVD or PVD deposition. The BARC layer is chosen so that it may act as an etch stop layer for an overlying dielectric such as an oxide. In FIG. 3, a buffer oxide layer **233** is shown overlying the BARC layer **231**. Finally, a metal shield layer **235** is formed overlying the buffer oxide layer **233**. The metal shield layer **235** may be tungsten, aluminum, copper or combinations such as AlCu. The deposition of the metal shield may be performed in a PVD process. When the device **200** is completed as further described herein, the metal shield layer **235** forms a light shield overlying the periphery region **207**, so that the circuitry formed in the periphery region **207** is not exposed to light impinging on the image sensor device, thus the operation of the CMOS transistors in the periphery region **207** will not be affected by light impinging on the device **200**.

FIG. 4 depicts, in a cross section, the embodiment image sensor device **200** during an etch process to remove certain layers over the sensor array region **205**. A photoresist layer **311** is formed over the semiconductor substrate **201** and patterned by photolithography to expose the metal shield layer **235** over the sensor array region **205**. The photoresist **311** remains over the periphery region **207**. An etch process is

5

used to selectively remove the metal shield **235** over the sensor array region **205**, while the photoresist **311** acts as an etch mask over the periphery region **207**. That is, a mask layer, such as the illustrated photoresist layer **311** or a hard mask layer or the like is formed over all or a portion of the periphery region **207**, but leaves the sensor array region **205** exposed. One skilled in the art will recognize how such a mask layer can be formed and patterned in this manner. Using one or more wet and/or dry etch processes, the metal shield layer **235** and the buffer oxide layer **233** are removed in the exposed sensor array region **205**, and any exposed portions of the periphery region **207**. In an example embodiment, a dry etch is used. As shown in FIG. 4, the etch process also removes a portion of the exposed regions of the BARC layer **231** (i.e. those portions in the sensor array region **205** and the portion exposed in the periphery region **207**). In contemplated embodiments, at least 10% of the original thickness of the BARC layer **231** will be removed in order to ensure that all remaining buffer oxide layer **233** has been removed. This is commonly referred to as an over-etch step or process. Removing a portion of the BARC layer **231** is done to completely remove the buffer oxide layer over the BARC layer in all portions of the sensor array area **205**. In an example process, the etch continues until at least 10% of the original BARC layer thickness is removed. In other embodiments, more than 10% of the original BARC layer thickness may be removed by the over-etch process. The etch process also forms a vertical sidewall in the oxide layer **233** and the metal shield **235** as shown in FIG. 4.

FIG. 5 is another cross sectional view that further illustrates the device **200** of FIG. 4 and in particular shows the results of the over-etch of the BARC layer **231**. The thickness  $t_0$  is the thickness of the BARC layer **231** that was removed by the etch process, and thickness  $t_0$  may be at least 10% of the thickness  $t_2$  of the BARC layer **231** over the periphery region **207**, which is the thickness of the BARC layer **231** prior to the etching. The thickness  $t_1$  shown in FIG. 5 indicates the thickness of the BARC layer **231** remaining over the array region **205** after the etch process. The thickness  $t_2$  indicates the thickness of the BARC layer over the periphery region, i.e. the portions that have not been over etched. In illustrative embodiments,  $t_1$  may be 90% or less of  $t_2$ .

FIG. 6 illustrates in another cross sectional view the embodiment image sensor device **200** following additional processing. After etch of the BARC layer **231** is completed as described above, a dielectric layer **237** is deposited over the back side **204** of the semiconductor substrate **201**. The dielectric layer **237** may also be an oxide and this may be described as an oxide re-deposition step, as the layer **237** replaces the buffer oxide **233** removed from the sensor array region **205** by the above described etch processes. The dielectric layer **237** may be deposited by a CVD process. In the sensor array region **205**, the oxide layer **237** now overlies the BARC layer **231**. In the periphery region **207**, the second dielectric or oxide layer **237** overlies the metal shield layer **235**. The layer **237** also forms a thickness  $t_3$  on the vertical sidewall of the metal shield layer **235**. Because this re-deposited oxide layer is deposited and is not then subsequently etched, a uniform thickness  $t_4$  of the layer **237** is easily obtained using known semiconductor processes. The thickness  $t_4$  of the layer **237** is highly uniform across the sensor array **205**, across a particular integrated circuit die, and also across the entire semiconductor wafer. In contemplated embodiments, the thickness uniformity of layer **237** will vary by perhaps less than 7% over a semiconductor wafer.

In FIG. 6,  $t_4$  represents the thickness of the dielectric layer **237** on the surface of the BARC layer **231** (in the sensor array

6

region **205**) and the surface of the metal shield **235** (in the periphery region **207**), i.e. the "horizontal" surfaces, whereas thickness  $t_3$  represents the thickness of the dielectric layer **237** on the vertical sidewall of the patterned layers (the metal shield layer **235**, the buffer oxide layer **233**, and the BARC layer **231** in the periphery region **207**). In the contemplated embodiments, the ratio of  $t_3/t_4$  is greater than about 40%.

In one example embodiment, the dielectric layer **237** is an oxide layer. While one skilled in the art will recognize various additional materials that could be employed for the dielectric film **237**, examples include  $\text{SiO}_2$ ,  $\text{SiN}$ ,  $\text{SiC}$ ,  $\text{SiON}$ ,  $\text{Ta}_2\text{O}_5$ ,  $\text{Al}_2\text{O}_3$ ,  $\text{HfO}$  or more complex films that are formed by combinations of these components. By controlling the thickness of the second dielectric layer **237** through process control of the dielectric deposition, and by selection of the material, the thickness and properties of the materials over the back side **204** of the semiconductor substrate **201** can be controlled. These control parameters provide a tuning mechanism for tuning the image sensor in different applications, controlling the light mean value achieved.

Also shown in FIG. 6 is a passivation layer **239** deposited over the substrate. In the sensor array region **205**, the passivation layer **239** is formed over the oxide layer **237** and the BARC layer **231**. In the periphery region **207**, the passivation layer **239** is formed over the oxide layer **237**, the metal shield layer **235**, the buffer oxide layer **233**, and the BARC layer **231**. The passivation layer may be silicon nitride, for example. The passivation layer **239** may be deposited by CVD, for example.

The thickness  $t_5$  in FIG. 6 represents the total film thickness above the array region **205**, i.e., the remaining thickness of the BARC layer **231** after the over-etch described above, the thickness  $t_4$  of the dielectric film **237**, and the thickness of the passivation layer **239**. If thickness  $t_5$  is too low, the color light mean of the resulting image sensor cannot be tuned. On the other hand, if thickness  $t_5$  is too thick, it may induce color cross talk. While various thickness ranges for  $t_5$  are within the contemplated scope of the claims, illustrative embodiments may have a thickness  $t_5$  in the range of from about 500 Å to about 8000 Å.

Following the deposition of the passivation layer **239** as shown in FIG. 6, processing of the BSI image sensor will continue. Color filter structures and microlens devices (not shown) may be formed over the passivation layer **239** of BSI device **200**. The color filter structures will selectively pass red, green and blue (R/G/B) frequency light onto corresponding photodiodes in the sensor array region **205**, so that color pixel elements may be formed.

FIG. 7 illustrates a method embodiment in a flow diagram. Beginning at stage **61**, a semiconductor substrate is provided with a sensor array region of photodiodes and a periphery region of circuitry. At stage **63**, an antireflective coating is formed over a back side of the semiconductor substrate. At stage **65**, a first dielectric layer is formed over the antireflective coating. At stage **67**, a metal shield layer is formed over the first dielectric layer.

At stage **69**, a photolithographic pattern and etch process is used to selectively remove the metal shield layer and the buffer oxide layer from the BARC layer over the sensor array, while the metal shield and the buffer oxide layer are retained over the devices in the periphery region. The etch process is continued to remove a portion of the BARC layer over the sensor array region, so as to ensure the buffer oxide layer is completely removed from the BARC layer over the sensor array region.

At stage **71**, a second dielectric layer, which may be an oxide layer, is formed over the substrate. In the sensor array

region, the second dielectric layer is deposited over the BARC layer. In the periphery region, the second dielectric layer is over the metal shield layer.

At stage 73, a passivation layer is formed over the dielectric layer. The thickness of the passivation layer, the second dielectric layer, and the BARC layer over the back side of the semiconductor substrate is formed to a thickness that is in a range of from about 500 Angstroms to about 8000 Angstroms.

Use of the embodiments results in a dielectric layer over a sensor array of photodiodes that has a uniform thickness. Further, the thickness of the layers over the sensor array and the material used may be controlled, and thus, the light path to the photodiodes in the sensor array may be tuned. This is in sharp contrast to the prior approaches. The R/G/B light mean ratio for the image sensor may be fine-tuned. The light mean uniformity and light mean value may be improved, as well as the QE and the SNR. The processes used in the embodiments are conventional semiconductor processes that are readily available and easily extended to future process nodes.

In an embodiment, a method for forming an image sensor includes providing a semiconductor substrate having a sensor array region and a periphery region and having a front side surface and an opposing back side surface; forming a bottom anti-reflective coating (BARC) over the back side surface of the semiconductor substrate to a first thickness, over the sensor array region and the periphery region; forming a first dielectric layer over the BARC; forming a metal shield over the first dielectric layer; selectively removing the metal shield from over the sensor array region; selectively removing the first dielectric layer from over the sensor array region, wherein a portion of the first thickness of the BARC is also removed and a remainder of the first thickness of the BARC remains, during the selectively removing the first dielectric layer; forming a second dielectric layer over the remainder of the first thickness of the BARC and over the metal shield over the periphery region; and forming a passivation layer over the second dielectric layer. In a further embodiment, in the above method the portion of the first thickness of the BARC removed is at least about 10% of the first thickness. In still another embodiment in the above method, the portion of the BARC that remains has a thickness that is less than about 90% of the first thickness. In yet another embodiment, in the above methods, forming the first dielectric layer includes forming buffer oxide.

In yet another embodiment, the above method further includes forming the second dielectric layer including depositing one selected from the group consisting essentially of SiO<sub>2</sub>, SiN, SiC, SiON, Ta<sub>2</sub>O<sub>5</sub>, Al<sub>2</sub>O<sub>3</sub>, HfO, and a complex film formed by combinations of these components. In still a further embodiment, in the above method, forming the second dielectric layer includes depositing one selected from the group consisting essentially of SiO<sub>2</sub>, SiN, SiC, SiON, Ta<sub>2</sub>O<sub>5</sub>, Al<sub>2</sub>O<sub>3</sub>, HfO, and a layer formed of combinations of these.

In still a further embodiment, in the above methods, following the forming of the passivation layer, a total thickness of the remainder of the first thickness of the BARC, the second dielectric layer, and the passivation layer over the sensor array region ranges from about 500 Å to about 8000 Å. In yet another embodiment, in the above method, forming the second dielectric layer includes forming a second dielectric layer that has a thickness that varies less than 7% in uniformity. In yet another embodiment, in the above method, the periphery region further includes CMOS transistors. In still another embodiment, the above methods include wherein a portion of the second dielectric layer formed over the sensor array region has a third thickness and a portion of the second dielectric layer formed on a vertical sidewall of the metal

shield after the selectively removing has a fourth thickness, and a ratio of the fourth thickness to the third thickness is greater than about 40%. In yet another embodiment, the above methods include wherein the selectively removing comprises performing a dry etch process, while the periphery region is protected by a photoresist layer.

In another embodiment, a BSI image sensor includes a semiconductor substrate having a sensor array region and a periphery region formed in the semiconductor substrate, and having a front side surface and a back side surface; a plurality of metallization layers formed in a dielectric layer overlying the front side surface of the semiconductor substrate; a BARC layer formed over the back side surface of the semiconductor substrate having a first thickness over the sensor array region, and a second greater thickness over the periphery region; a first dielectric layer formed over the BARC layer in the periphery region; a metal shield layer formed over the first dielectric layer in the periphery region; a second dielectric layer formed over the back side of the semiconductor substrate over the first thickness of the BARC layer over the sensor array region, and over the metal shield over the periphery region; and a passivation layer formed over the second dielectric layer; wherein a total thickness of the BARC layer, the second dielectric layer, and the passivation layer over the sensor array region ranges from about 500 Å to about 8000 Å.

In another embodiment, the BSI image sensor is provided wherein the first dielectric layer comprises a buffer oxide. In still a further embodiment, in the BSI image sensor above, the second dielectric layer includes one selected from the group consisting essentially of SiO<sub>2</sub>, SiN, SiC, SiON, Ta<sub>2</sub>O<sub>5</sub>, Al<sub>2</sub>O<sub>3</sub>, HfO, and a complex film formed by combinations of these components. In a further embodiment, the BSI image sensor is provided wherein the second dielectric layer an oxide layer. In yet another embodiment, the BSI image sensor is provided and the second dielectric layer has a thickness over sensor array region that is a first thickness, and a thickness over a vertical sidewall of the metal shield over the periphery region that is a second thickness, and a ratio of the second thickness to the first thickness is greater than about 40%. In still a further embodiment, the BSI image sensor is provided wherein the first thickness of the BARC layer is less than about 90% of the second thickness of the BARC layer. In yet another embodiment, the BSI image sensor is provided wherein the wherein the second dielectric layer has a thickness that varies less than 7% in uniformity.

In yet another embodiment, a BSI image sensor is provided including a semiconductor substrate having a front side surface and a back side surface; a plurality of photodiodes formed in a sensor array region of the semiconductor substrate; a plurality of CMOS transistors formed in a periphery region adjacent the sensor array region of the semiconductor substrate; a BARC layer overlying the back side surface of the semiconductor substrate having a first thickness in the sensor array region and a second thickness greater than the first thickness in the periphery region; a buffer oxide layer overlying the BARC layer in the periphery region but not in the sensor array region; a metal shield layer overlying the buffer oxide layer in the periphery region; a second dielectric layer overlying the BARC layer in the sensor array region and overlying the metal shield layer in the periphery region, the second dielectric layer being one selected from the group consisting essentially of SiO<sub>2</sub>, SiN, SiC, SiON, Ta<sub>2</sub>O<sub>5</sub>, Al<sub>2</sub>O<sub>3</sub>, HfO, and a complex film formed by combinations of these components; and a passivation layer over the second dielectric layer. In a further embodiment, the BSI image sensor includes wherein a total thickness of the first thickness of

9

the BARC layer, the second dielectric layer, and the passivation layer over the sensor array region ranges from about 500 Å to about 8000 Å.

While the embodiments are described herein with reference to illustrative embodiments, this description is not intended to be construed in a limiting sense. Various modifications and combinations of the illustrative embodiments, as well as other embodiments, will be apparent to persons skilled in the art upon reference to the description. For example, although in the illustrative embodiments CMOS photodiodes are described as the photosensitive elements, CCD devices could also be used. It is therefore intended that the appended claims encompass any such modifications or embodiments.

What is claimed is:

1. A method of forming an image sensor, the method comprising:

receiving a substrate having a sensor array region and a periphery region, the substrate having a front side surface and a back side surface;

forming a plurality of metallization layers overlying the front side surface of the substrate;

forming a bottom anti-reflective coating (BARC) layer over the back side surface of the substrate, the BARC layer having a first thickness over the sensor array region and a second thickness over the periphery region, the second thickness being greater than the first thickness;

forming a metal shield over the second thickness of the BARC layer; and

forming one or more dielectric layers over the metal shield and the first thickness of the BARC layer.

2. The method of claim 1, wherein the first thickness is about 90% of the second thickness.

3. The method of claim 1, further comprising forming a buffer oxide between the BARC layer and the metal shield.

4. The method of claim 1, wherein a total thickness of the one or more dielectric layers and the BARC layer over the sensor array region ranges from about 500 Å to about 8000 Å.

5. The method of claim 1, wherein the one or more dielectric layers comprises a first dielectric layer that varies less than 7% in uniformity.

6. The method of claim 1, wherein the one or more dielectric layers comprises a first dielectric layer, the first dielectric layer having a third thickness over the sensor array region and a fourth thickness along sidewalls of the metal shield, a ratio of the fourth thickness to the third thickness is greater than about 40%.

7. The method of claim 1, wherein the forming the BARC layer comprises forming an initial BARC layer and removing a portion of the initial BARC layer over the sensor array region.

8. A method of forming an image sensor, the method comprising:

receiving a substrate having first side and a second side, the substrate having a photosensitive element in a first region on the first side and other circuitry in a second region on the first side;

forming a BARC layer formed over the second side of the substrate, the BARC layer having a first thickness over the second side of the substrate opposite the photosensitive element and a second thickness over the second side of the substrate opposite the other circuitry, the first thickness being different than the second thickness;

forming a first dielectric layer formed over the second thickness of the BARC layer;

forming a metal shield layer formed over the first dielectric layer; and

10

forming one or more dielectric layers over the metal shield layer and over the first thickness of the BARC layer; wherein a total thickness of the BARC layer and the one or more dielectric layers opposite the photosensitive element is between about 500 Å to about 8,000 Å.

9. The method of claim 8, wherein the forming the BARC layer, forming the first dielectric layer, and forming the metal shield comprises:

forming a uniform BARC layer over the second side of the substrate opposite the photosensitive element and the other circuitry;

forming a uniform first dielectric layer over the second side of the substrate opposite the photosensitive element and the other circuitry;

forming a uniform metal shield layer over the second side of the substrate opposite the photosensitive element and the other circuitry; and

removing the uniform first dielectric layer and the uniform metal shield layer on the second side of the substrate opposite the photosensitive element; and

removing a portion of the uniform BARC layer over the second side of the substrate opposite the photosensitive element.

10. The method of claim 8, wherein the first thickness is about 90% of the second thickness.

11. The method of claim 8, wherein the first dielectric layer comprises an oxide.

12. The method of claim 8, wherein a total thickness of the one or more dielectric layers and the BARC layer over the second side of the substrate opposite the photosensitive element ranges from about 500 Å to about 8000 Å.

13. The method of claim 8, wherein the one or more dielectric layers comprises a first dielectric layer that varies less than 7% in uniformity.

14. The method of claim 8, wherein the one or more dielectric layers comprises a first dielectric layer, the first dielectric layer having a third thickness over the second side of the substrate opposite the photosensitive element and a fourth thickness along sidewalls of the metal shield, a ratio of the fourth thickness to the third thickness is greater than about 40%.

15. A method of forming an image sensor, the method comprising:

receiving a substrate having a first side and a second side; forming a plurality of photosensitive elements in a first region on the first side of the substrate;

forming circuitry in a second region adjacent the first region on the first side of the substrate;

forming a BARC layer overlying the second side of the substrate having a first thickness in the first region and a second thickness different than the first thickness in the second region;

forming a buffer layer over the BARC layer in the second region, the buffer layer not extending over the first region; and

forming a metal shield layer over the buffer layer in the second region.

16. The method of claim 15, further comprising forming a one or more dielectric layers directly over the metal shield in the second region and directly over the BARC layer in the first region.

17. The method of claim 16, wherein a total thickness of the one or more dielectric layers and the BARC layer in the first region ranges from about 500 Å to about 8000 Å.

18. The method of claim 16, wherein the one or more dielectric layers comprises a first dielectric layer that varies less than 7% in uniformity.

**11**

**19.** The method of claim **16**, wherein the one or more dielectric layers comprises a first dielectric layer, the first dielectric layer having a third thickness over the first region and a fourth thickness along sidewalls of the metal shield, a ratio of the fourth thickness to the third thickness is greater than about 40%.

**20.** The method of claim **15**, wherein the first thickness is less than about 90% of the second thickness.

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**12**